

## A study of winter avifaunal diversity in Upper Lake, in the City of Bhopal, Madhya Pradesh, India

Hyder Ali Rather<sup>1\*</sup>  and Varsha Gautam<sup>2</sup> 

<sup>1</sup>Department of Life Science, Rabindranath Tagore University, Raisen, Madhya Pradesh, India

<sup>2</sup>Department of Zoology, Govt. PG College, Bareilly, Raisen, Madhya Pradesh, India

\*Corresponding author ✉: [hyderalirather54321@gmail.com](mailto:hyderalirather54321@gmail.com)

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### Abstract

Avifauna is an important constituent, as well as an important link in the food chain, of every ecosystem. Birds are regarded as important biological indicators since they can live in a variety of settings and are environmentally adaptive. Wetlands are important bird habitats and birds use them for breeding, nesting and rearing young. Upper Lake is a tropical wetland in Bhopal, the capital city of Madhya Pradesh, and harbors rich biodiversity. This study documents the avifaunal diversity around Upper Lake, Bhopal over a period of four successive years (2018–2021). To assess bird diversity, the point-count method was used but opportunistic spotting was also included. During the survey, a total of 158 avian species, belonging to 18 orders, 52 families and 115 genera were recorded. Out of 18 orders, Passeriformes had the highest avian species richness (67 species). At the family level, Muscicapidae and Anatidae were the most dominant families with 13 species each. The results, derived from various diversity indices (Shannon-Weiner, Margalef and Pielou), suggest that Upper Lake, Bhopal supports rich avifaunal diversity. However, certain anthropogenic threats pose serious threats to the avifaunal diversity. Habitat destruction and degradation pose the most significant threat with hunting of various migratory water birds and threatened species as a growing concern. Therefore, to ensure continued diversity within the region, it is recommended that these anthropogenic activities be regularly monitored and kept to a minimum.

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**Key words:** Anthropogenic activity, Bhopal, Muscicapidae, Point-count, Shannon-Weiner index

### Introduction

The study of diversity and distribution patterns of organisms, and their function in ecosystems is quite challenging (Gayan et al., 2022). Birds are known to maintain the balance of an ecosystem (Padmavathy et al., 2010) by influencing the nutrient flow, and also playing a significant role in various food webs, mainly as pollinators and predators (Whelan et al., 2008). Water birds (birds that live on or around water) that spend whole days on, or near, the lake can contribute to nutrient cycling; principally by sharing two ecosystems (aquatic and terrestrial) for their daily needs; and ultimately causing nutrient translocation (Adhurya et al., 2020). Specific bird species assemblages are also good

indicators of ecosystem integrity and function (Hossain and Aditya, 2016). Recent literature has noted that bird populations are declining due to habitat destruction, anthropogenic activity and climate change (Rapoport, 1993; Crick, 2004; Ahola et al., 2007; Chen et al., 2011; Mengesha et al., 2014; Richard et al., 2021). Of the 1341 birds found on the Indian subcontinent (Praveen et al., 2021), Madhya Pradesh state is home to about 456 species, of which 305 exist in the capital city of Bhopal (eBird, 2022). Studies of avifaunal diversity from different parts of India, encompassing different habitat types, are commonly published (Roy et al., 2011, 2012a, 2012b; Mukhopadhyay and Mazumdar, 2017; Changder et al., 2017; Adhurya et al., 2019, 2022).

The present study was carried out with the aims of: 1) checking the status of bird diversity in and around the Upper Lake, 2) assembling a checklist of this avifauna and 3) identify anthropogenic factors affecting the bird diversity.

## Material and Methods

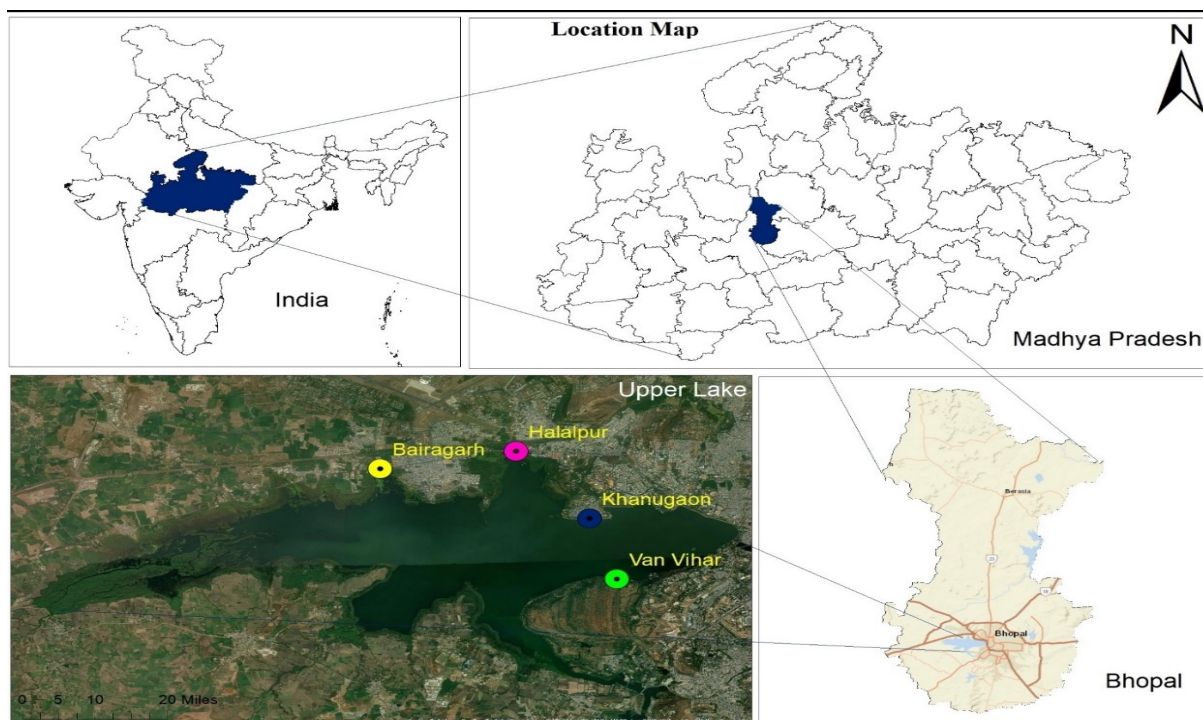
### Study area

Upper Lake is an east-west orientated, elongate urban lake, which receives water from the river Kolans and local precipitation. The lake is the main source of drinking water for the residents of the city of Bhopal (Fig. 1). Upper Lake (Bhojtal) was created by Raja Bhoj (King of the Parmar dynasty and ruler of Malwa region) during 1005–1055 AD (Vyas et al., 2010). The lake was known as the Upper Lake or Bada Talab (Big Pond) until March 2011 when it was renamed Bhojtal in honor of the Great King Raja Bhoj who built it. This lake was formed by constructing an earthen dam across the Kolans River and it has a catchment area of 361 sq. km and a mean depth of 3.16 m, with a maximum depth of 11.64 m. The excess water from the Upper Lake flows into the Kaliasot River which meets Betwa River and drains into the Yamuna River. The altitude of Upper Lake is about 503 m above mean sea level and it is situated at 23°16' N latitude and 77°25' E longitude. In Bhopal, the wet season is oppressive and overcast, the dry season is mostly clear, and it is hot year-round. Over the course of the year, the temperature typically varies from 53 °F to 104 °F and is rarely below 47 °F or above 109 °F. The lake is

bordered by human settlements on the eastern and northern boundaries while its western margins are used for intensive agriculture. The southern shore of the lake borders Van Vihar National Park. The irregular margins of the lake support dense growth of aquatic macrophytes like *Eichhornia crassipes*, *Spirodella polyrhiza*, *Wolffia globosa*, *Pistia*, *Aponogeton natans*, *Nymphaeoids nouchali*, and *Hydrilla*, and sustains a diverse aquatic fauna (Vyas et al., 2010).

### Field survey

Field survey was carried out from 2018–2021. The survey was made twice a week for the entire study period. Birds were observed during the most active periods of the day, in the mornings (06:00 to 10:00 hours) and late afternoons (16:30 to 19:00 hours). Nocturnal bird survey observations were made during early dawn and late dusk (05:00 to 06:00; 18:00 to 20:00). The bird survey was conducted using the point-count method, but opportunistic spotting also added species to the list. Birds were observed using 8X40 magnification Olympus binoculars and identified using suitable field guides (Grewal et al., 2002; Grimmett et al., 2012). Photographs were taken using DSLR (Nikon D3400) and Point and Shoot Cameras (Nikon Coolpix B700 and Nikon Coolpix P900) (Appendix). The family, common names and scientific names of the birds follow the checklist of Praveen et al. (2021). The IUCN status of the birds is given following the IUCN (2023); as LC- Least Concern, CR- Critically Endangered, EN- Endangered, RA- Rare, NT- Near Threatened, VU- Vulnerable.



**Figure 1:** Location of the Upper Lake, Bhopal in India (above left), in Madhya Pradesh (above right) and its satellite image (below). Map prepared using GIS software.

The data collected was used to estimate the diversity of the avifauna species. Various diversity indices were estimated using PAST 4.05: Richness (S), Shannon Diversity Index (H) (Shannon, 1948), Pielou's Evenness Index (J) (Pielou, 1966), Margalef's Diversity Index (Margalef, 1968) and Berger-Parker Dominance (d) Index (Berger and Parker, 1970).

Shannon's Diversity Index,  $H = -\sum ni$

Here,  $n_i$  is the number of individuals of a particular species and H is the total number of individuals covering all species.

Pielou's Evenness Index,  $J = H/\ln S$

Margalef's Diversity Index =  $S - 1/\ln N$

Here, S= Number of species and N= Total number of individuals.

Berger-Parker's dominance,  $D = \frac{N_{max}}{N}$

Here,  $N_{max}$  is the number of individuals of a species having a maximum count.

The species accumulation curve was prepared using MS Excel.

## Results

A total of 158 avian species belonging to 18 orders, 52 families and 115 genera were observed during the study. Among the 52 families, Muscicapidae and Anatidae were the most dominant with 13 species each, followed by Ardeidae with 9 species.

Out of 18 orders, Passeriformes had the highest avian species richness (67 species), followed by Charadriiformes (16 species), Anseriformes (13 species), Pelecaniformes (10 species), Columbiformes and Accipitriformes (8 species each), Coraciiformes (7 species), Gruiformes (5 species), Ciconiiformes, Cuculiformes and Galliformes (4 species each), Suliformes (3 species), Piciformes, Psittaciformes and Falconiformes (2 species each), whereas orders with a minimum number of species each were Bucerotiformes, Caprimulgiformes and Podicipediformes (1 species each).

The Sarus Crane *Antigone antigone* (Linnaeus, 1758), River Tern *Sterna aurantia* Gray JE, 1831, Greater Spotted Eagle *Clanga clanga* (Pallas, 1811) and Common Pochard *Aythya ferina* (Linnaeus, 1758) were all recorded during the study and are considered as Vulnerable (VU) according to the IUCN Red List of Threatened Species (IUCN, 2023). Moreover, two Near Threatened species, the Painted Stork *Mycteria leucocephala* (Pennant, 1769) and the Oriental Darter *Anhinga melanogaster* Pennant, 1769, were also recorded during the study. The observed Critically Endangered species were Indian Vulture *Gyps indicus* (Scopoli, 1786), and White-rumped vulture *Gyps bengalensis* (Gmelin, 1788) and there was one Endangered Species, the Egyptian Vulture *Neophron percnopterus* (Linnaeus, 1758).

The migratory status of the birds in the study were that 48 species were migratory, 109 were residents, and one was a local migrant. A detailed checklist of the birds, along with their scientific names and yearly presence or absence is given in (Table 1).

The results of the diversity indices for the different years of the study are provided in (Table 2). The highest Shannon-Wiener diversity index was observed in 2019 (0.1543) whereas the lowest was during 2018 (0.1434). According to Pielou's evenness index, it is seen that 2018 and 2020 (0.577) are the most evenly distributed years, followed by 2019 (0.5829) and 2021 (0.578). Margalef's index is generally concerned with species richness and both indices have the highest values during the year 2018 and the lowest values during 2020. The Berger-Parker dominance index shows a maximum value during 2021 (0.9673) and minimum value during 2019 (0.9645).

The number of winter avifauna species in Upper Lake is generally increasing over time due to the increased involvement of researchers and extensive explorations. The number of avifauna species was 132 in 2018, 152 in 2019, 154 in 2020 and 140 in 2021 (Fig. 2). Three species of bird, the Greater spotted Eagle, White-rumped Vulture and Sarus crane were all only recorded during the first two years of the study (2018 and 2019). In contrast, the Black Redstart was not recorded during the first two years of the study but was observed from the third year onwards.

## Discussion

During our study Muscicapidae and Anatidae were the most dominant families. Vyas et al. (2010) while working on Upper Lake, Bhopal, recorded 43 species, belonging to 14 families and 8 orders with family Anatidae as the most dominant family represented by ten species, followed by family Ardeidae represented by 8 species. Our results reveal a total of 158 avian species belonging to 18 orders, 52 families and 115 genera during the study period. This is similar to the study conducted by the Madhya Pradesh State biodiversity board through the Environmental Conservation Society (Bhopal Birds) in 2016, revealing a total number of 164 bird species from Upper Lake, Bhopal. Vyas and Veerwal (2014) and (Veerwal et al., 2014) both recorded 68 species of birds from Upper Lake, Bhopal in 2014. Rather and Shrivastava (2021) also found 70 bird species from Upper Lake, Bhopal, but Rather et al. (2022) later found 49 species during the summer and 43 species from October 2019 to March 2020. The Deputy Director of Van Vihar National Park, (Jain, 2021), reported 207 species of birds from Bhoj Wetland, Bhopal, during December 2021 to January 2022. Patowari (2019) of the Times of India, reported 119 migratory bird species visiting Bhopal during the winter of 2019. However, in another report by (Khalique, 2020) 125 bird species were observed in the Bhoj wetland, Bhopal.

**Table 1:** Winter avifaunal species recorded during the present study from the Upper Lake, Bhopal, India. (Abbreviations used: M- Migratory, R- Resident, LM, Local Migrant, LC- Least Concern, CR- Critically Endangered, EN- Endangered, NT- Near Threatened, VU- Vulnerable).

| S.No. | Family          | Common name               | Scientific name                                    | IUCN status 2022 | Migratory status |
|-------|-----------------|---------------------------|--|------------------|------------------|
| 1     | Emberizidae     | Red-headed Bunting        | <i>Emberiza bruniceps</i> Brandt, 1841             | LC               | M                |
| 2     | Emberizidae     | Black-headed Bunting      | <i>Emberiza melanocephala</i> Scopoli, 1769        | LC               | M                |
| 3     | Emberizidae     | Crested Bunting           | <i>Emberiza lathami</i> Gray, JE, 1831             | LC               | M                |
| 4     | Emberizidae     | Grey-necked Bunting       | <i>Emberiza buchanani</i> Blyth, 1845              | LC               | M                |
| 5     | Motacillidae    | Tawny Pipit               | <i>Anthus campestris</i> (Linnaeus, 1758)          | LC               | M                |
| 6     | Motacillidae    | Paddy-field Pipit         | <i>Anthus rufulus</i> Vieillot, 1818               | LC               | R                |
| 7     | Motacillidae    | Pied Wagtail              | <i>Motacilla alba</i> Linnaeus, 1758               | LC               | R                |
| 8     | Motacillidae    | White-browed Wagtail      | <i>Motacilla maderaspatensis</i> Gmelin, J.F. 1789 | LC               | M                |
| 9     | Motacillidae    | Grey Wagtail              | <i>Motacilla cinerea</i> Tunstall, 1771            | LC               | M                |
| 10    | Passeridae      | House Sparrow             | <i>Passer domesticus</i> (Linnaeus, 1758)          | LC               | R                |
| 11    | Passeridae      | Yellow-throated Sparrow   | <i>Gymnoris xanthocollis</i> (Burton, 1838)        | LC               | R                |
| 12    | Dicruridae      | Black Drongo              | <i>Dicrurus macrocercus</i> Vieillot, 1817         | LC               | R                |
| 13    | Dicruridae      | Ashy Drongo               | <i>Dicrurus leucophaeus</i> Vieillot, 1817         | LC               | R                |
| 14    | Dicruridae      | White-bellied Drongo      | <i>Dicrurus caerulescens</i> (Linnaeus, 1758)      | LC               | R                |
| 15    | Dicaeidae       | Thick-billed Flowerpecker | <i>Dicaeum agile</i> (Tickell, 1833)               | LC               | R                |
| 16    | Muscicapidae    | Pied Bush Chat            | <i>Saxicola caprata</i> (Linnaeus, 1766)           | LC               | M                |
| 17    | Muscicapidae    | Siberian Stonechat        | <i>Saxicola maurus</i> (Pallas, 1773)              | LC               | M                |
| 18    | Muscicapidae    | Blue Rock Thrush          | <i>Monticola solitarius</i> (Linnaeus, 1758)       | LC               | M                |
| 19    | Muscicapidae    | Verditer Flycatcher       | <i>Eumyias thalassinus</i> (Swainson, 1838)        | LC               | M                |
| 20    | Muscicapidae    | Oriental Magpie-Robin     | <i>Copsychus saularis</i> (Linnaeus, 1758)         | LC               | R                |
| 21    | Muscicapidae    | Ultramarine Flycatcher    | <i>Ficedula superciliaris</i> (Jerdon, 1840)       | LC               | R                |
| 22    | Muscicapidae    | Black Redstart            | <i>Phoenicurus ochruros</i> (Gmelin, S.G., 1774)   | LC               | M                |
| 23    | Muscicapidae    | Bluethroat                | <i>Luscinia svecica</i> (Linnaeus, 1758)           | LC               | M                |
| 24    | Muscicapidae    | Indian Robin              | <i>Copsychus fulicatus</i> (Linnaeus, 1766)        | LC               | R                |
| 25    | Muscicapidae    | Variable Wheatear         | <i>Oenanthe picata</i> (Blyth, 1847)               | LC               | M                |
| 26    | Muscicapidae    | Brown Rock Chat           | <i>Oenanthe fusca</i> (Blyth, 1851)                | LC               | R                |
| 27    | Muscicapidae    | Tickell's Blue Flycatcher | <i>Cyornis tickelliae</i> Blyth, 1843              | LC               | R                |
| 28    | Muscicapidae    | Asian Brown Flycatcher    | <i>Muscicapa dauurica</i> Pallas, 1811             | LC               | R                |
| 29    | Leiotherichidae | Jungle Babbler            | <i>Turdoides striata</i> (Dumont, 1823)            | LC               | R                |
| 30    | Leiotherichidae | Common Babbler            | <i>Turdoides caudate</i> (Dumont, 1823)            | LC               | R                |
| 31    | Zosteropidae    | Indian White-eye          | <i>Zosterops palpebrosus</i> (Temminck, 1824)      | LC               | R                |
| 32    | Cisticolidae    | Plain Prinia              | <i>Prinia inornate</i> Sykes, 1832                 | LC               | R                |
| 33    | Cisticolidae    | Ashy Prinia               | <i>Prinia socialis</i> Sykes, 1832                 | LC               | R                |
| 34    | Cisticolidae    | Common Tailorbird         | <i>Orthotomus sutorius</i> (Pennat, 1769)          | LC               | R                |
| 35    | Cisticolidae    | Zitting Cisticola         | <i>Cisticola juncidis</i> (Rafinesque, 1810)       | LC               | R                |
| 36    | Cisticolidae    | Rufous-fronted Prinia     | <i>Prinia buchanani</i> Blyth, 1844                | LC               | R                |
| 37    | Paridae         | Cinereous Tit             | <i>Parus cinereus</i> Vieillot, 1818               | LC               | M                |
| 38    | Corvidae        | House Crow                | <i>Corvus splendens</i> Vieillot, 1817             | LC               | R                |
| 39    | Corvidae        | Large-billed Crow         | <i>Corvus macrorhynchos</i> Wagler, 1827           | LC               | R                |
| 40    | Laniidae        | Long-tailed Shrike        | <i>Lanius schach</i> Linnaeus, 1758                | LC               | M                |
| 41    | Laniidae        | Bay-backed Shrike         | <i>Lanius vittatus</i> Valenciennes, 1826          | LC               | M                |
| 42    | Rhipiduridae    | White-browed Fantail      | <i>Rhipidura aureola</i> Lesson, 1831              | LC               | R                |
| 43    | Rhipiduridae    | Spot-breasted Fantail     | <i>Rhipidura albogularis</i> (Lesson, 1831)        | LC               | R                |
| 44    | Rhipiduridae    | White-throated Fantail    | <i>Rhipidura albicollis</i> (Vieillot, 1818)       | LC               | R                |
| 45    | Hirundinidae    | Red-rumped Swallow        | <i>Cecropis daurica</i> (Laxmann, 1769)            | LC               | R                |
| 46    | Hirundinidae    | Wire-tailed Swallow       | <i>Hirundo smithii</i> Leach, 1818                 | LC               | R                |
| 47    | Hirundinidae    | Barn Swallow              | <i>Hirundo rustica</i> Linnaeus, 1758              | LC               | R                |
| 48    | Sturnidae       | Asian Pied Starling       | <i>Gracupica contra</i> (Linnaeus, 1758)           | LC               | R                |
| 49    | Sturnidae       | Brahminy Starling         | <i>Sturnia pagodarum</i> (Gmelin, JF, 1789)        | LC               | R                |
| 50    | Sturnidae       | Chestnut-tailed Starling  | <i>Sturnia malabarica</i> Gmelin, 1789             | LC               | R                |
| 51    | Sturnidae       | Rose-coloured Starling    | <i>Pastor roseus</i> (Linnaeus, 1758)              | LC               | R                |
| 52    | Sturnidae       | Common Myna               | <i>Acridotheres tristis</i> (Linnaeus, 1766)       | LC               | R                |
| 53    | Ploceidae       | Baya Weaver               | <i>Ploceus philippinus</i> (Linnaeus, 1766)        | LC               | R                |
| 54    | Ploceidae       | Streaked weaver           | <i>Ploceus manyar</i> (Horsfield, 1821)            | LC               | R                |

Table 1: (Continued).

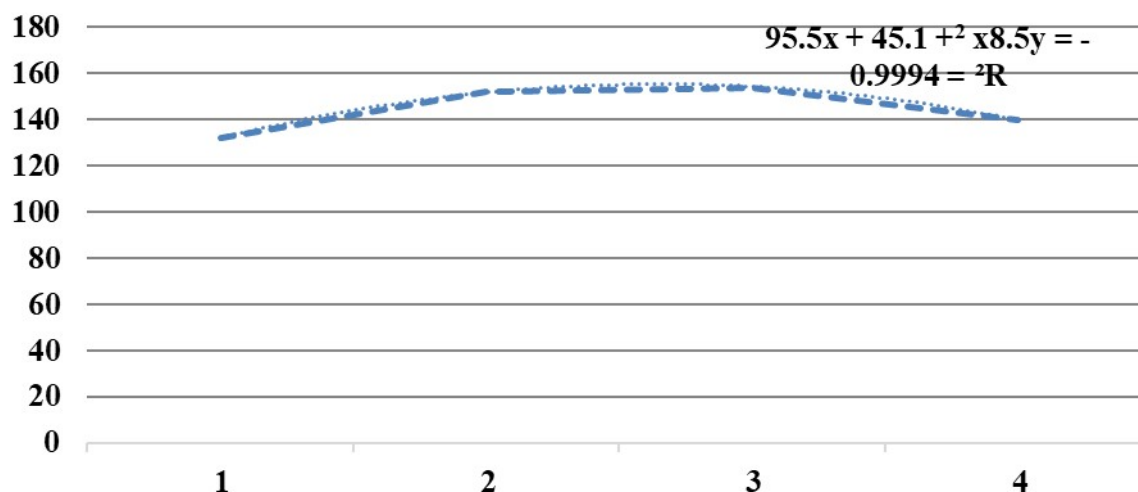
| S.No. | Family            | Common name                   | Scientific name  | IUCN status |                  |
|-------|-------------------|-------------------------------|--|-------------|------------------|
|       |                   |                               |  | 2022        | Migratory status |
| 55    | Nectariniidae     | Purple-rumped Sunbird         | <i>Leptocoma zeylonica</i> (Linnaeus, 1766)              | LC          | R                |
| 56    | Nectariniidae     | Purple Sunbird                | <i>Cinnyris asiaticus</i> (Latham, 1790)                 | LC          | R                |
| 57    | Estrildidae       | Red Avadavat                  | <i>Amandava amandava</i> (Linnaeus, 1758)                | LC          | R                |
| 58    | Estrildidae       | Indian Silverbill             | <i>Euodice malabarica</i> (Linnaeus, 1758)               | LC          | R                |
| 59    | Chloropseidae     | Jerdon's Leafbird             | <i>Chloropsis jerdoni</i> (Blyth, 1844)                  | LC          | R                |
| 60    | Stenostiridae     | Grey-headed Canary-Flycatcher | <i>Culicicapa ceylonensis</i> (Swainson, 1820)           | LC          | R                |
| 61    | Pycnonotidae      | Red-vented Bulbul             | <i>Pycnonotus cafer</i> (Linnaeus, 1766)                 | LC          | R                |
| 62    | Pycnonotidae      | Red-whiskered Bulbul          | <i>Pycnonotus jocosus</i> (Linnaeus, 1758)               | LC          | R                |
| 63    | Monarchidae       | Indian Paradise-Flycatcher    | <i>Terpsiphone paradise</i> (Linnaeus, 1758)             | LC          | R                |
| 64    | Alaudidae         | Ashy-crowned Sparrow-lark     | <i>Eremopteryx griseus</i> (Scopoli, 1786)               | LC          | M                |
| 65    | Alaudidae         | Oriental Skylark              | <i>Alauda gulgula</i> Franklin, 1831                     | LC          | M                |
| 66    | Campephagidae     | Small Minivent                | <i>Pericrocotus cinnamomeus</i> (Linnaeus, 1766)         | LC          | R                |
| 67    | Campephagidae     | Long-tailed Minivent          | <i>Pericrocotus ethologus</i> Bangs & Phillips, JC, 1914 | LC          | R                |
| 68    | Burhinidae        | Indian Thick-knee             | <i>Burhinus indicus</i> (Salvadori, 1866)                | LC          | R                |
| 69    | Scolopacidae      | Common Sandpiper              | <i>Actitis hypoleucos</i> (Linnaeus, 1758)               | LC          | M                |
| 70    | Scolopacidae      | Ruff                          | <i>Calidris pugnax</i> (Linnaeus, 1758)                  | LC          | M                |
| 71    | Scolopacidae      | Black-tailed Godwit           | <i>Limosa limosa</i> (Linnaeus, 1758)                    | LC          | R                |
| 72    | Scolopacidae      | Common Snipe                  | <i>Gallinago gallinago</i> (Linnaeus, 1758)              | LC          | M                |
| 73    | Scolopacidae      | Spotted Redshank              | <i>Tringa erythropus</i> (Pallas, 1764)                  | LC          | M                |
| 74    | Laridae           | River Tern                    | <i>Sterna aurantia</i> Gray, JE, 1831                    | VU          | R                |
| 75    | Laridae           | Black-headed Gull             | <i>Chroicocephalus ridibundus</i> (Linnaeus, 1766)       | LC          | M                |
| 76    | Glareolidae       | Small Pratincole              | <i>Glareola lactea</i> Temminck, 1820                    | LC          | R                |
| 77    | Charadriidae      | Little Ringed Plover          | <i>Charadrius dubius</i> Scopoli, 1786                   | LC          | R                |
| 78    | Charadriidae      | Yellow-wattled Lapwing        | <i>Vanellus malabaricus</i> (Boddaert, 1783)             | LC          | R                |
| 79    | Charadriidae      | Red-wattled Lapwing           | <i>Vanellus indicus</i> (Boddaert, 1783)                 | LC          | R                |
| 80    | Charadriidae      | Kentish Plover                | <i>Charadrius alexandrinus</i> (Linnaeus, 1758)          | LC          | M                |
| 81    | Turnicidae        | Barred Buttonquail            | <i>Turnix suscitator</i> (Gmelin, JF, 1789)              | LC          | R                |
| 82    | Jacaniidae        | Bronze-winged Jacana          | <i>Metopidius indicus</i> (Latham, 1790)                 | LC          | M                |
| 83    | Jacaniidae        | Pheasant-tailed Jacana        | <i>Hydrophasianus chirurgus</i> (Scopoli, 1786)          | LC          | M                |
| 84    | Anatidae          | Lesser Whistling-Duck         | <i>Dendrocygna javanica</i> (Horsfield, 1821)            | LC          | LM               |
| 85    | Anatidae          | Common Pochard                | <i>Aythya ferina</i> (Linnaeus, 1758)                    | VU          | M                |
| 86    | Anatidae          | Northern Shoveler             | <i>Spatula clypeata</i> (Linnaeus, 1758)                 | LC          | M                |
| 87    | Anatidae          | Gadwall                       | <i>Mareca strepera</i> (Linnaeus, 1758)                  | LC          | M                |
| 88    | Anatidae          | Knob-billed Duck              | <i>Sarkidiornis melanotos</i> (Pennat, 1769)             | LC          | M                |
| 89    | Anatidae          | Ruddy Shelduck                | <i>Tadorna ferruginea</i> (Pallas, 1764)                 | LC          | M                |
| 90    | Anatidae          | Red-crested Pochard           | <i>Netta rufina</i> (Pallas, 1773)                       | LC          | M                |
| 91    | Anatidae          | Eurasian Wigeon               | <i>Mareca penelope</i> (Linnaeus, 1758)                  | LC          | M                |
| 92    | Anatidae          | Bar-headed Goose              | <i>Anser indicus</i> (Latham, 1790)                      | LC          | M                |
| 93    | Anatidae          | Garganey                      | <i>Spatula querquedula</i> (Linnaeus, 1758)              | LC          | M                |
| 94    | Anatidae          | Indian Spot-billed Duck       | <i>Anas poecilorhyncha</i> Forster, 1781                 | LC          | R                |
| 95    | Anatidae          | Asian Pygmy- Goose            | <i>Nettapus coromandelianus</i> (Gmelin, JF, 1789)       | LC          | M                |
| 96    | Anatidae          | Common Teal                   | <i>Anas crecca</i> Linnaeus, 1758                        | LC          | M                |
| 97    | Threskiornithidae | Indian Black Ibis             | <i>Pseudibis papilosa</i> (Temminck, 1824)               | LC          | R                |
| 98    | Ardeidae          | Great White Egret             | <i>Ardea alba</i> Linnaeus, 1758                         | LC          | R                |
| 99    | Ardeidae          | Intermediate Egret            | <i>Ardea intermedia</i> Wagler, 1829                     | LC          | R                |
| 100   | Ardeidae          | Little Egret                  | <i>Egretta garzetta</i> (Linnaeus, 1766)                 | LC          | R                |
| 101   | Ardeidae          | Indian Pond Heron             | <i>Ardeola garyii</i> (Sykes, 1832)                      | LC          | R                |
| 102   | Ardeidae          | Cattle Egret                  | <i>Bubulcus ibis</i> (Linnaeus, 1758)                    | LC          | R                |
| 103   | Ardeidae          | Purple Heron                  | <i>Ardea purpurea</i> Linnaeus, 1766                     | LC          | R                |
| 104   | Ardeidae          | Grey Heron                    | <i>Ardea cinerea</i> Linnaeus, 1758                      | LC          | R                |
| 105   | Ardeidae          | Black Bittern                 | <i>Ixobrychus flavicollis</i> (Latham, 1790)             | LC          | R                |
| 106   | Ardeidae          | Cinnamon Bittern              | <i>Ixobrychus cinnamomeus</i> (Gmelin, 1789)             | LC          | M                |
| 107   | Columbidae        | Rock Pigeon                   | <i>Columba livia</i> Gmelin, JF, 1789                    | LC          | R                |
| 108   | Columbidae        | Pale-backed Pigeon            | <i>Columba eversmanni</i> Bonaparte, 1856                | LC          | R                |
| 109   | Columbidae        | Spotted-necked Dove           | <i>Streptopelia chinensis</i> (Scopoli, 1786)            | LC          | R                |
| 110   | Columbidae        | Laughing Dove                 | <i>Streptopelia senegalensis</i> (Linnaeus, 1766)        | LC          | R                |
| 111   | Columbidae        | Oriental Turtle Dove          | <i>Streptopelia orientalis</i> (Latham, 1790)            | LC          | R                |

**Table 1: (Continued).**

| S.No. | Family            | Common name                | Scientific name                                     | IUCN status 2022 | Migratory status |
|-------|-------------------|----------------------------|---|------------------|------------------|
| 112   | Columbidae        | Yellow-legged Green-Pigeon | <i>Treron phoenicopterus</i> (Latham, 1790)         | LC               | R                |
| 113   | Columbidae        | Eurasian Collared Dove     | <i>Streptopelia decaocto</i> (Frisvaldszky, 1838)   | LC               | R                |
| 114   | Columbidae        | Red Collared Dove          | <i>Streptopelia tranquebarica</i> (Hermann, 1804)   | LC               | R                |
| 115   | Accipitridae      | Indian Vulture             | <i>Gyps indicus</i> (Scopoli, 1786)                 | CE               | R                |
| 116   | Accipitridae      | Crested Honey-buzzard      | <i>Pernis ptilorhynchus</i> (Temminck, 1821)        | LC               | R                |
| 117   | Accipitridae      | Egyptian Vulture           | <i>Neophron percnopterus</i> (Linnaeus, 1758)       | EN               | R                |
| 118   | Accipitridae      | Black-winged Kite          | <i>Elanus caeruleus</i> (Desfontaines, 1789)        | LC               | R                |
| 119   | Accipitridae      | Greater Spotted Eagle      | <i>Clanga clanga</i> (Pallas, 1811)                 | VU               | M                |
| 120   | Accipitridae      | Black Kite                 | <i>Milvus migrans</i> (Boddaert, 1783)              | LC               | R                |
| 121   | Accipitridae      | White-rumped Vulture       | <i>Gyps bengalensis</i> (Gmelin, JF, 1788)          | CE               | R                |
| 122   | Accipitridae      | Booted Eagle               | <i>Hieraetus pennatus</i> (Gmelin, 1788)            | LC               | R                |
| 123   | Alcedinidae       | Stork-billed Kingfisher    | <i>Pelargopsis capensis</i> (Linnaeus, 1766)        | LC               | R                |
| 124   | Alcedinidae       | White-throated Kingfisher  | <i>Halcyon smyrnensis</i> (Linnaeus, 1758)          | LC               | R                |
| 125   | Alcedinidae       | Pied Kingfisher            | <i>Ceryle rudis</i> (Linnaeus, 1758)                | LC               | R                |
| 126   | Alcedinidae       | Common Kingfisher          | <i>Alcedo atthis</i> (Linnaeus, 1758)               | LC               | R                |
| 127   | Meropidae         | Green Bee-eater            | <i>Merops orientalis</i> Latham, 1801               | LC               | R                |
| 128   | Meropidae         | Blue-tailed Bee-eater      | <i>Merops philippinus</i> Linnaeus, 1767            | LC               | M                |
| 129   | Coraciidae        | Indian Roller              | <i>Coracias benghalensis</i> (Linnaeus, 1758)       | LC               | R                |
| 130   | Gruidae           | Sarus Crane                | <i>Antigone antigone</i> (Linnaeus, 1758)           | VU               | R                |
| 131   | Rallidae          | Eurasian Coot              | <i>Fulica atra</i> Linnaeus, 1758                   | LC               | M                |
| 132   | Rallidae          | Eurasian Moorhen           | <i>Gallinula chloropus</i> (Linnaeus, 1758)         | LC               | R                |
| 133   | Rallidae          | White-breasted Waterhen    | <i>Amaurornis phoenicurus</i> (Pennant, 1769)       | LC               | R                |
| 134   | Rallidae          | Grey-headed Swamphen       | <i>Porphyrio poliocephalus</i> (Latham, 1801)       | LC               | R                |
| 135   | Ciconiidae        | Black Stork                | <i>Ciconia nigra</i> (Linnaeus, 1758)               | LC               | R                |
| 136   | Ciconiidae        | Woolly-necked Stork        | <i>Ciconia episcopus</i> (Boddaert, 1783)           | LC               | R                |
| 137   | Ciconiidae        | Asian Openbill             | <i>Anastomus oscitans</i> (Boddaert, 1783)          | LC               | M                |
| 138   | Ciconiidae        | Painted Stork              | <i>Mycteria leucocephala</i> (Pennant, 1769)        | NT               | R                |
| 139   | Cuculidae         | Greater Coucal             | <i>Centropus sinensis</i> (Stephens, 1815)          | LC               | R                |
| 140   | Cuculidae         | Pied Cuckoo                | <i>Clamator jacobinus</i> (Boddaert, 1783)          | LC               | M                |
| 141   | Cuculidae         | Common Hawk-Cuckoo         | <i>Hierococcyx varius</i> (Vahl, 1797)              | LC               | M                |
| 142   | Cuculidae         | Asian Koel                 | <i>Eudynamis scolopaceus</i> (Linnaeus, 1758)       | LC               | R                |
| 143   | Phasianidae       | Rain Quail                 | <i>Coturnix coromandelica</i> (Gmelin, JF, 1789)    | LC               | M                |
| 144   | Phasianidae       | Painted Francolin          | <i>Francolinus pictus</i> (Jardine & Selby, 1828)   | LC               | R                |
| 145   | Phasianidae       | Grey Francolin             | <i>Francolinus pondicerianus</i> (Gmelin, JF, 1789) | LC               | R                |
| 146   | Phasianidae       | Indian Peafowl             | <i>Pavo cristatus</i> Linnaeus, 1758                | LC               | R                |
| 147   | Anhingidae        | Oriental Darter            | <i>Anhinga melanogaster</i> Pennant, 1769           | NT               | M                |
| 148   | Phalacrocoracidae | Little Cormorant           | <i>Microcarbo niger</i> (Vieillot, 1817)            | LC               | R                |
| 149   | Phalacrocoracidae | Indian Cormorant           | <i>Phalacrocorax fuscicollis</i> Stephens, 1826     | LC               | R                |
| 150   | Picidae           | Black-rumped Woodpecker    | <i>Dinopium benghalense</i> (Linnaeus, 1758)        | LC               | R                |
| 151   | Picidae           | Brown-capped Woodpecker    | <i>Dendrocopos moluccensis</i> (Vigors, 1832)       | LC               | R                |
| 152   | Psittaculidae     | Ring-necked Parakeet       | <i>Psittacula krameri</i> (Scopoli, 1769)           | LC               | R                |
| 153   | Psittaculidae     | Plum-headed Parakeet       | <i>Psittacula cyanocephala</i> (Linnaeus, 1766)     | LC               | R                |
| 154   | Upupidae          | Eurasian Hoopoe            | <i>Upupa epops</i> Linnaeus, 1758                   | LC               | R                |
| 155   | Caprimulgidae     | Jungle Nightjar            | <i>Caprimulgus indicus</i> Latham, 1790             | LC               | R                |
| 156   | Falconidae        | Common Kestrel             | <i>Falco tinnunculus</i> Linnaeus, 1758             | LC               | M                |
| 157   | Falconidae        | Red-necked Falcon          | <i>Falco chicquera</i> Daudin, 1800                 | LC               | R                |
| 158   | Podicipedidae     | Little Grebe               | <i>Tachybaptus ruficollis</i> (Pallas, 1764)        | LC               | R                |

**Table 2:** Diversity indices for different years (2018–2021) for the water birds of Upper Lake, Bhopal, India.

| Diversity index    | Years  |        |        |        |
|--------------------|--------|--------|--------|--------|
|                    | 2018   | 2019   | 2020   | 2021   |
| No. of Species     | 132    | 152    | 154    | 140    |
| No. of Individuals | 3928   | 4128   | 456    | 4102   |
| Shannon_H          | 0.1434 | 0.1534 | 0.1439 | 0.145  |
| Evenness_e^H/S     | 0.5771 | 0.5829 | 0.5774 | 0.578  |
| Margalef           | 0.1204 | 0.1196 | 0.1182 | 0.1197 |
| Berger-Parker      | 0.9675 | 0.9645 | 0.9673 | 0.967  |



**Figure 2:** Species Accumulation Curve with a forecast using Log regression fit. [In the Curve, Year 1= 2017–18 and as follows].

Our results also reveal an increasing trend of avian species numbers through the successive years of the study; however, a change during the last year (2020) with slightly lower total is aberrant. A possible cause for this lower total species count may be the influence of the Covid -19 pandemic restricting survey and the involvement of more people.

## Conclusion

Considering the present study, and the available literature, it can be concluded that Upper Lake is continuously supporting rich biodiversity in respect to avifauna. We have observed very diverse avifaunal species, which includes migratory birds, vulnerable species, threatened species and critically endangered species like the Indian Vulture (*Gyps indicus*) and White-rumped vulture (*Gyps bengalensis*). As our results reveal there is an increasing trend of avian species throughout the successive years of study with the exception of 2020. There are certain anthropogenic threats, like habitat destruction and degradation, which pose the most significant threats to avian populations in this area. Hunting of various migratory water birds and threatened species is also a growing concern. It is recommended that hunting and anthropogenic impacts on the local bird species should be closely monitored.

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## Author contributions

Hyder Ali Rather collected all the data from field and wrote the manuscript with support from Dr. Varsha Gautam. Dr. Varsha Gautam took the lead in writing the manuscript and also helped in making the checklist.

Both authors provided critical feedback and helped shape the research, analysis and manuscript.

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## Conflict of interest

The authors declare that there are no conflicting issues related to this research article.

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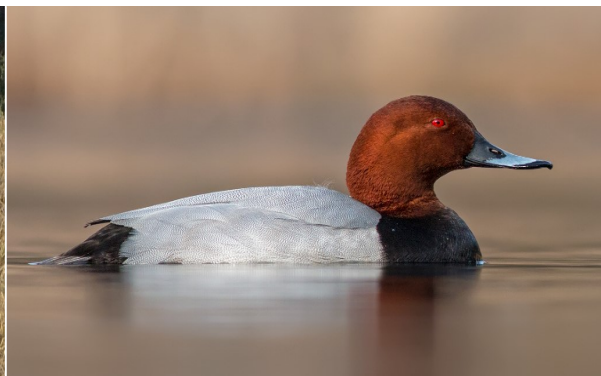
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**Appendix:** Some Threatened Species of the Upper Lake, Bhopal, India.



*Antigone antigone* (Photo by Hyder Ali Rather)



*Aythya ferina* (Photo by Hyder Ali Rather)



*Sterna aurantia* (Photo by Varsha Gautam)



*Clanga clanga* (Photo by Hyder Ali Rather)